Toxicity of Some Herbicidal Sprays to Honey Bees[1,2,3]

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ABSTRACT

Various formulations and combinations of herbicides and carriers were sprayed on small cages containing *Apis mellifera* L. Daily counts of dead bees were made for 14 days after treatment to determine toxicity. Monosodium methanearsonate (MSMA), paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride salt), and cacodylic acid (hydroxydimethylarsine oxide) were highly toxic. Diesel oil and Mobilsol 1605 (phytobland oil) caused high mortality the 1st 24 hr after treatment and very little the following days. Combinations of diesel oil-water and diesel oil-water-dimethylsulfoxide (DMSO) were less toxic than diesel oil alone but more toxic than water. Several formulations and combinations of 2,4-D ((2,4-dichlorophenoxy) acetic acid); 2,4,5-T ((2,4,5-trichlorophenoxy) acetic acid); silvex (2-(2,4,5-trichlorophenoxy) propionic acid); and picloram (4-amino-3,5,6-trichloropicolinic acid) were nontoxic when applied in a water carrier as were endothall (amine salt of 7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid), and a 1:1 mixture of the triethylamine salts of 2,4,5-T and picloram.

Most previous studies indicate that herbicides are relatively nontoxic to honey bees, *Apis mellifera* L., yet reports of field losses from herbicides continue. In this study we attempted to find out if spraying field concentrations of herbicides would be toxic to honey bees in small cages.

Hocking (1959) stated that most herbicides cause more loss to beekeepers through loss of forage than through loss of bees, although the arsenic compounds, sodium fluoride, and 4,6-dinitro-*o*-cresol (DNOC) may cause severe losses.

King (1961[7]) immersed bees in aqueous formulations of herbicides for 10 sec and found that DNBP (2-*sec*-butyl-4,6-dinitrophenol); dalapon (2,2-dichloropropionic acid); and ester formulations of 2,4-D ((2,4-dichlorophenoxy) acetic acid) and 2,4,5-T ((2,4,5-trichlorophenoxy) acetic acid) caused high mortality. However, amine formulations of MCPA ((4-chloro-*o*-tolyl) oxy acetic acid); 4-(2,4-DB) ((4-(2,4-dichlorophenoxy) butyric acid); 4-(MCPB) (4-((4-chloro-*o*-tolyl) oxy) butyric acid); amitrole (3-amino-*s*-triazole); and TCA (trichloroacetic acid) were nontoxic to bees.

Palmer-Jones (1950), Byrdy (1962), and Dallmann (1962) found 2,4-D to be nontoxic to bees in field dosages. Palmer-Jones (1964) reported that aerial application of 2,4-D superphosphate dust mixture on ragwort in New Zealand caused a 20% loss in the field force and the loss of the honey crop over a large area. He reported no adverse effect on brood or hive activity 12 and 16 days after treatment.

The New Zealand Agricultural Chemical Board (1961) wrote that early work showed 2,4-D to be safe but that recent large-scale field usages have resulted in bee losses.

Palmer-Jones (1960) found 2,4,5-T safe for honey bees in the field. Anderson and Atkins (1968) found 2,4-D, 2,4,5-T, and paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride salt) to be relatively nontoxic to honey bees. Later, Atkins et al. (1969[8]) reported that picloram (4-amino-3,5,6-trichloropicolinic acid), Weedar[9] (a commercial formulation of the dimethylamine salt of 2,4-D), and cacodylic acid (hydroxydimethylarsine oxide) also were relatively nontoxic to honey bees.

MATERIALS AND METHODS.—*Test 1.*—A ½-acre cage 10 ft high containing a heavy stand of London rocket, *Sisymbrium irio,* was divided into 4 equal parts, each 75×70 ft. Four nuclei were moved into each part on Feb. 17, 1969, 1 week before spraying, to allow bees to become conditioned to the cage. Dead-bee traps were placed on each hive, and dead bees were counted daily.

Immediately before the sprays were applied, four 5×5×5-in. wire cages, each containing ca. 75 adult bees, were placed in each subcage. Dead bees in these small cages were counted 24 and 48 hr after sprays were applied.

[1] Hymenoptera: Apidae.
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[3] Mention of a proprietary product does not constitute endorsement by the USDA.
[4] Entomology Research Division.
[5] Plant Science Research Division.
[6] C. C. King. 1961. Effects of herbicides on honey bees and nectar secretion. Ph.D. thesis. Ohio State University, Columbus. 177 p.
[7] E. L. Atkins, Jr., L. D. Anderson, and E. A. Greywood. 1969. Effect of pesticides on apiculture. Univ. Calif., Riverside, Dep. Entomol., Annu. Rep. Proj. 1459.

Table 1.—Percentage of adult bees confined in small cages which died before and after being sprayed with 2,4-D in February 1969 at Tucson, Ariz.[a]

Spray formulation[b]	Dead bees		
	4 hr before spraying	Hours after spraying	
		24	48
Water check	2.2	1.7	1.7
Dimethylamine salt of 2,4-D in water	12.8	0.5	1.9
Butoxyethyl ester of 2,4-D in water	7.8	6.3	29.6[c]
Butoxyethyl ester of 2,4-D in diesel oil and water (1:3)	1.3	3.1	3.8
LSD	NS	NS	NS

[a] All values are average of 4 cages in each sprayed area.
[b] All sprays applied at rate of 1 lb AI/acre in volume equivalent to 20 gal/acre.
[c] All bees in 1 cage died.

The London rocket was sprayed with 4 materials on February 24, 1969, between 1:30 and 3 PM. One part was sprayed with water, the 2nd was sprayed with dimethylamine salt of 2,4-D in water, the 3rd was treated with butoxyethyl ester of 2,4-D in water, and the 4th received butoxyethyl ester of 2,4-D in a 1:3 diesel oil-water spray. These 2,4-D treatments were applied at rate of 1 lb AI/acre and at a volume of 20 gal/acre. A surfactant, polyethylene tridecyl ether (with 6 moles of ethylene oxide), was added to all sprays except the water check at a concentration of 0.5% (vol/vol) of the total volume of spray. Sprays were applied directly over the small cages but not directly over the dead-bee traps and nuclei.

All Other Tests.—All other tests were conducted from October 1969 through May 1970. With a vacuum cleaner we collected ca. 50 honey bees from entrances of colonies in the experimental apiary in individual cages (2×2×6 in.). These bees were then brought into the laboratory and fed 60% sucrose syrup and distilled water.

The next day, dead bees were removed from the cages, and cages with the remaining live bees were taken outside and sprayed with the test material. After the spray dried, the caged bees were brought back into the laboratory. Daily counts were made of dead bees in each cage for 14 days after spraying. Five replications of each treatment were included in each test. A water spray was one of the treatments in each test.

Unless otherwise specified, all herbicides were applied at a rate of 4 lb AI/acre in a carrier volume of 20 gal/acre with a compressed-air sprayer equipped with a 3-nozzle boom. Cages were placed on the ground, and the boom was passed 18 in. above the tops of the cages. Calibration of the sprayer and application of sprays to empty cages showed that ca. 25% of the spray penetrated the screen and was deposited on the bees and the floor of the cage. Assuming the other 75% of the spray was deposited on the screen, the herbicide could come in contact with the bees as they walked on the screen or could remain on the screen without making contact with the bees. Multi-Film X-77[2], a nonionic blended surfactant which consists of alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol, was added to all the sprays at a concentration of 0.1% (vol/vol).

Test 2.—Three herbicides, paraquat (Paraquat CL[3]), dimethylamine salt of 2,4-D (DMA-4), and monosodium methanearsonate (MSMA) (Ansar 170[3]), were applied in aqueous solution.

Test 3.—The potassium salt of picloram (Tordon 22K[3]), the triethylamine salt of 2,4,5-T, and a mixture of triisopropylamine salts of picloram and 2,4-D (1:2 wt/wt) (Tordon 212[3]) were applied in water carrier. The propylene glycol butyl ether ester of silvex (2-(2,4,5-trichlorophenoxy) propionic acid) (Kuron[3]) was sprayed in a 1:3 diesel oil-water carrier.

Test 4.—The butoxy ethyl ester of 2,4,5-T (Special Air Spray Formula[3]) was applied in water, diesel oil, and 1:3 diesel oil-water. Cacodylic acid (Phytar 560[3]) was applied in water.

Test 5.—The propylene glycol butyl ether esters of silvex were applied in water, 1:3 diesel oil-water, diesel oil, and a 2:3:3 mixture of diesel oil-water-dimethyl sulfoxide.

Test 6.—Weedar 64[2] and DMA-4[2], commercial formulations of the dimethylamine salt of 2,4-D, and 1 formulation of the isooctyl ester of 2,4-D (Chipman 133[3]) were applied in water. The isooctyl ester of 2,4-D was applied also in 1:3 diesel oil-water.

Test 7.—The treatments were: endothall (amine salt of 7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid) (Des-I-Cate[2]) applied at a rate of 1 lb/acre in water; propylene glycol butyl ether ester of silvex in water; and a 1:1 mixture of triethylamine salts of 2,4,5-T and picloram (Tordon 225[3]) in water and in 1:3 diesel oil-water.

Test 8.—Mortality caused by different carriers was studied. The treatments were: no spray, water spray only, 1:3 diesel oil-water, diesel oil, and phytobland oil (Mobilsol 100[3]).

Table 2.—Dead bees in traps placed on nuclei in cages containing London rocket which was sprayed with different formulations of 2,4-D in February 1969 at Tucson.[a]

Spray formulation[b]	7 days before spraying	Time after spraying			
		1 day	1 wk	2 wk	3 wk
Water check	20	6	17	54	21
Dimethylamine salt of 2,4-D in water	25	16	56	54	50
Butoxyethyl ester of 2,4-D in water	63	18	32	37	33
Butoxyethyl ester of 2,4-D in diesel oil and water (1:3)	50	18	50	44	24
$LSD_{0.05}$	NS	NS	NS	NS	NS

[a] All values are average number per day calculated from 4 traps in each sprayed area, with spray applied to vegetation only, not to hives and traps.
[b] All sprays applied at rate of 1 lb AI/acre in volume equivalent to 20 gal/acre.

RESULTS.—Immediately after the spraying in test 1, the bees in the 4 cages sprayed with 2,4-D in diesel oil-water carrier were lying on the bottom of the cages. However, these bees recovered and appeared normal the next day. Mortality was not statistically significant between any of the treatments and the water check (Table 1). All bees in 1 cage treated with butoxyethyl ester of 2,4-D in water died, but the variability between cages was greater than the difference between the treatments. The number of bees in the dead-bee traps was greater for nuclei in plots treated with 2,4-D than for nuclei in untreated plots (Table 2); however, these differences were not significant, and dead-bee counts were not high for any of the treatments. (Although the numbers of dead bees in the traps do not represent total mortality for each colony, the percentage of dead bees found in each trap should remain constant for each.) The London rocket died after treatment with 2,4-D, but in the water (check) spray treatment it continued to grow and was visited by bees.

In test 2, paraquat and MSMA were extremely toxic to sprayed bees (Fig. 1). The rate of mortality of bees sprayed with dimethylamine salt of 2,4-D was similar to that of the check bees.

In test 3, bees sprayed with picloram in water, 2,4,5-T in water, or picloram + 2,4-D had rates of mortality (Fig. 2) similar to that of the check group. Bees sprayed with the ester of silvex in diesel oil-water had 33% mortality the 1st day. Subsequent

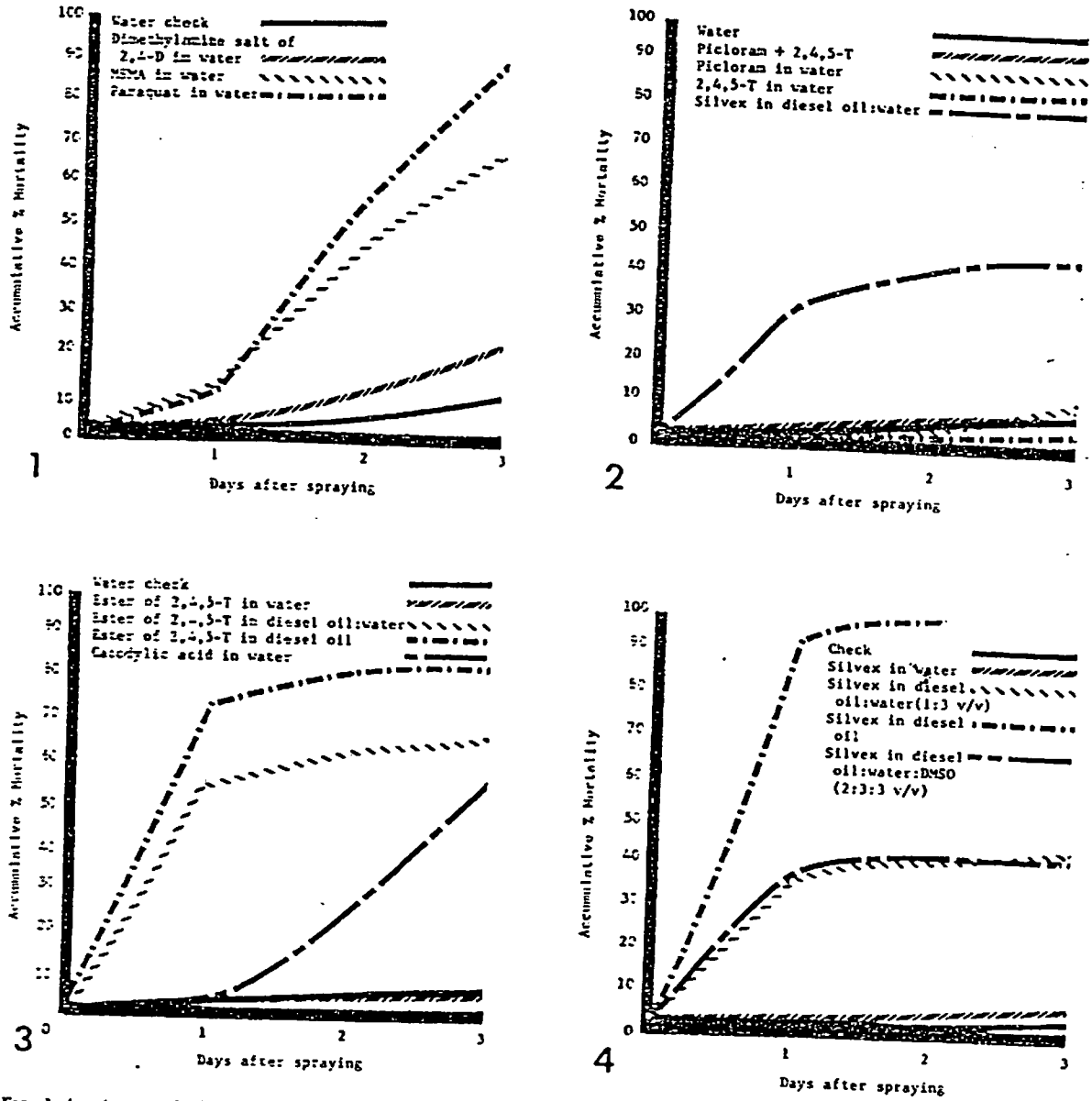

FIG. 1–4.—Accumulative mortality of bees. FIG. 1.—Sprayed with a 4 lb/acre rate of 2,4-D, paraquat, MSMA, and water check. FIG. 2.—Sprayed with aqueous sprays of picloram, picloram + 2,4-D, 2,4,5-T, and silvex in diesel oil:water, and water check. FIG. 3.—Sprayed with ester of 2,4,5-T in water, diesel oil:water, and diesel oil carriers; cacodylic acid in water; and water check. FIG. 4.—Sprayed with silvex in water, silvex in diesel oil:water silvex in diesel oil, and silvex in a 2:3:3 combination of diesel oil: water: DMSO.

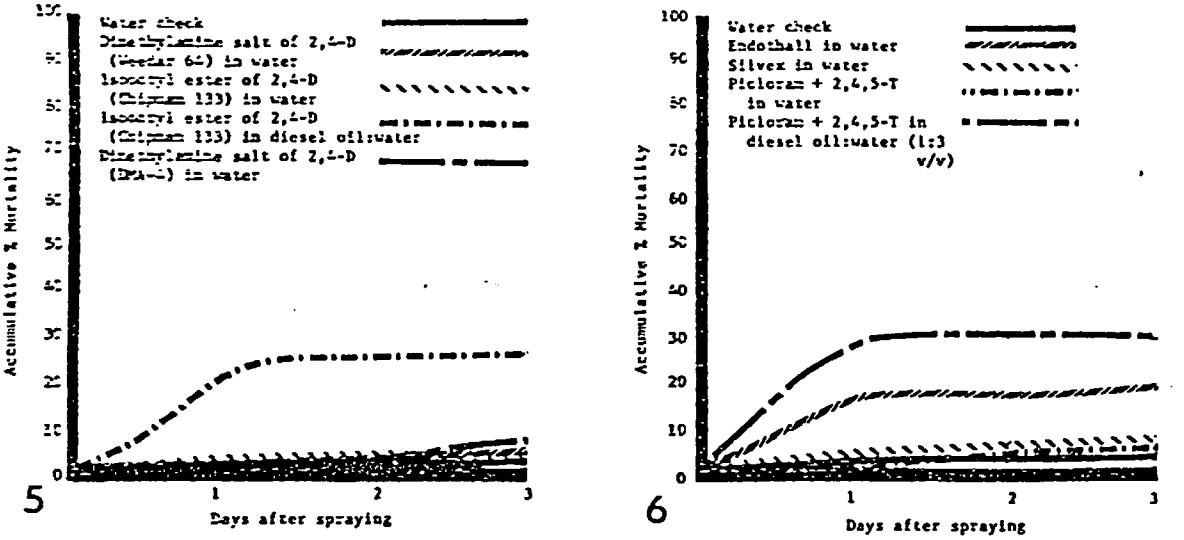

FIG. 5, 6.—Accumulative mortality of bees. FIG. 5.—Sprayed with commercial formulations of 2,4-D in water or diesel oil-water carriers. FIG. 6.—Sprayed with endothall, silvex, and picloram + 2,4,5-T in water; and picloram + 2,4,5-T in diesel oil:water.

daily rates of mortality were low, and by the 9th day after spraying, accumulative mortality was similar to that of other sprays.

In the 4th test, bees sprayed with ester of 2,4,5-T in water had mortality similar to that of bees in the check cages (Fig. 3). Ester of 2,4,5-T in both diesel oil and diesel oil-water carriers killed more than 60% of the bees the 1st 2 days; however, the bees had low rates of mortality for the remaining 12 days. Few bees sprayed with cacodylic acid died the 1st day, but mortality was high the 2nd–5th day, and all were dead after 10 days.

In test 5, daily mortality was about the same for bees treated with the silvex in water carrier and in the water check (Fig. 4). The treatment containing silvex in the diesel oil-water and silvex in the diesel oil-water-dimethyl sulfoxide carrier had ca. 35% mortality the 1st day after spraying; however, rates after the 1st day were about equal to the rates in the water check and in the silvex in water treatments. The rate of mortality of bees in cages sprayed with silvex and diesel oil was 96% the 1st day after treatment.

In test 6, bees sprayed with 2 formulations of dimethylamine salt of 2,4-D and the isooctyl ester of 2,4-D in water had almost the same mortality as the check bees (Fig. 5). However, bees sprayed with the isooctyl ester of 2,4-D in diesel oil-water had 20% mortality the 1st day, but on succeeding days mortality was similar to that of the other 4 treatments.

In test 7, bees sprayed with silvex, and picloram + 2,4,5-T in water all had low rates of mortality for 3 days after treatment and slightly higher mortality than the water check after the 3rd and 4th days (Fig. 6). Bees sprayed with picloram + 2,4,5-T in diesel oil-water had 30% mortality the 1st day, but mortality leveled off and was low for the rest of the test. Bees sprayed with endothall had high mortality the 1st and 3rd days after treatment.

In test 8, bees sprayed with either diesel oil or Mobilsol 100 had 45% mortality the 1st day compared with 14% for the diesel oil-water carrier and 1% for both the water spray and no spray checks (Fig. 7), but after the 1st day, daily mortality was similar for the treatments and the checks.

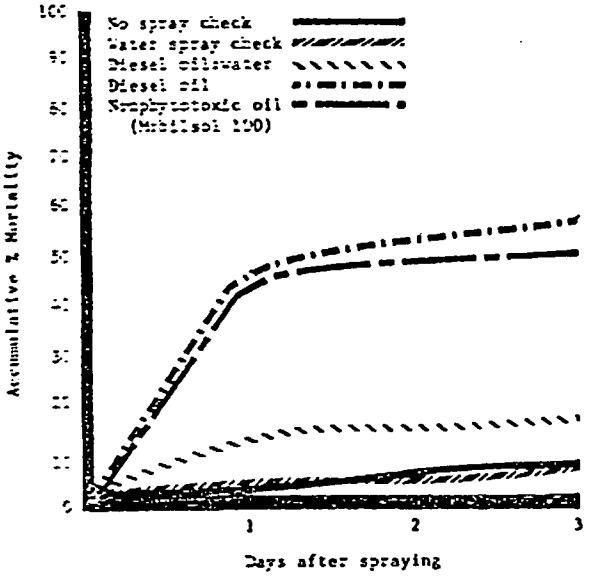

FIG. 7.—Accumulative mortality of bees sprayed with diesel oil, Mobilsol 100, diesel oil:water, and water.

DISCUSSION.—MSMA, paraquat, and cacodylic acid were highly toxic to honey bees in small cages when applied as water sprays.

Various formulations (amine salts and esters) of 2,4-D, 2,4,5-T, silvex, and picloram were nontoxic to bees when applied in water carrier. Diesel oil showed considerable toxicity the 1st day after spraying. Diesel oil-water and diesel oil-water-DMSO combination carriers were less toxic than straight diesel oil, but more toxic than water alone. The substituted phenoxy and picolinic acid herbicides have

relatively low toxicity to honey bees, but the oil carriers are toxic to bees.

Endothall was moderately toxic to honey bees. Mobilsol 100, an oil of very low phytotoxicity, was toxic when sprayed on bees.

The studies indicated that the carrier used to apply the herbicides is sometimes toxic to honey bees. Conflicting reports concerning toxicity of herbicides to honey bees may result partly from the difference in the carriers used and partly from the actual herbicide.

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